National Renewable Energy Laboratory

TRIP REPORT

To: **Biotechnology Center for Fuels and Chemicals**

From: **R. Wooley**

Destination: San Francisco, CA

Purpose: Attend National Conference on Ethanol Policy and Marketing: Sugar Platform (The Bioenergy Initiative Approach)

Date: 3/22-24/00

Abstract: This presentation quickly describes that the sugar platform is a term applied to the production of intermediate sugars from lignocellulosic biomass. By developing a common platform to fermentable sugars a multitude array of products, including ethanol, but not limited to ethanol can be produced. These other products can be much more valuable, but will generally have a smaller market. These other products will be a way to ease the revenue to an ethanol plant and help justify the risk of initial plants with higher financial returns. The new technology is described that allows sugars to be produced as an intermediate product and also touches on other, higher value opportunities for the lignin by-product.

Keywords: Sugar Platform, fermentable products, process economics, lignin uses

Sugar Platform

(BioEnergy Initiative Approach)

National Conference on Ethanol Policy & Marketing
March 22-24, 2000
San Francisco, CA

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Outline

- What is a “Sugar Platform”?
- Why is it Possible?
- Process Opportunities
- Products and Costs from Sugar
- Lignin Upgrading Opportunities
- Summary

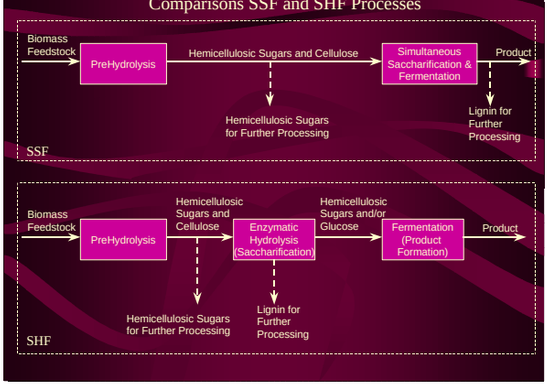
What is a “Sugar Platform”?

- A natural intermediate of ethanol production is the production of pentose and hexose sugars and relatively pure lignin
  - Basecase process converts sugar to ethanol and lignin to power & steam
  - DOE recognizes that sugar and lignin can be converted to other higher value products that may help jump start biomass conversion industry
  - DOE is interested in supporting the utilization of biomass sugars to advance the core biomass hydrolysis technology

What is a “Sugar Platform”? (Continued)

- Replace the Simultaneous Saccharification and Fermentation with Sequential Hydrolysis and Fermentation
- Decoupling of Hydrolysis and Fermentation offers various processing advantages and opportunities
- Can serve existing sugar markets, as well as supply sugar for fermentations

Comparisons SSF and SHF Processes



Why is SHF Possible Now?

- Modern metabolic engineering tools have improved its viability
- Enzymatic conversion of cellulose is generally product inhibited by Cellobiose
- With genetically engineered enzymes systems:
  - β-Glucosidase can be increased
  - β-Glucosidase removes the cellobiose and minimizes the product inhibition

Opportunities with a Sugar Intermediate Stream

- By decoupling hydrolysis and fermentation, the cellulase enzyme and the fermentation organism no longer have to operate under the same conditions
  - Enzymes can operate at high temperature for increased performance
  - Microoganisms can operate a moderate temperatures with emphasis on performance in hostile chemical environments and utilization of sugars
- Microorganism could potentially be recycled in no-solids fermentation
- Sugar is available for production of Higher Value Products

Higher Value Products from Sugar Stream

	Market MM lb/yr	Price $/lb	Yield lb/ton	Fraction of Market**	Revenue*** MM $/yr
Ethanol*	93,600	$ 0.15	593	0.5%	$ 68
Acetic Acid	3,400	$ 0.33	574	13%	$ 146
Butyraldehyde	2,100	$ 0.43	287	11%	$ 95
Adipic Acid	1,600	$ 0.65	860	41%	$ 431
Butanol	1,000	$ 0.41	287	22%	$ 91
Acrylic Acid	1,000	$ 0.69	918	71%	$ 488
Succinic Acid	600	$ 0.35	998	128%	$ 210
Propylene Glycol	600	$ 0.58	310	40%	$ 138
Glycerol	350	$ 0.58	574	126%	$ 203
Citric Acid	350	$ 0.82	998	220%	$ 287
Propionic Acid	100	$ 0.41	528	406%	$ 41
Butyric Acid	30	$ 0.48	436	1119%	$ 14
Malic acid	15	$ 0.81	642	3297%	$ 12
2,3-butanediol		$ 0.90	379		

* Assuming 10% of Gasoline Market
** Based on one 2000 T biomass/day plant
** Based on one 2000 T biomass/day plant or 100% of Market

Cost of Sugar Production

- Sugar production from biomass is projected to be:
  - Near Term 6.4¢ to 5.7¢ per lb
  - 2005 4.4¢ per lb
  - 2010 3.9¢ to 3.0¢ per lb
- This compares favorably with current costs of glucose:
  - ~6¢ per lb (estimated corn wet mill)

Upgrading Lignin

- Lignin from either process can be:
  - Burned to produce steam and electricity
  - Depolymerized and hydrotreated to yield branched aromatic fuel additives
  - Chemically converted to fuel additives
  - Converted to other valuable chemicals
  - Gasified for power production
  - Gasified for fermentation

Higher Value Products from Lignin Stream

- Fuel Additives
  - Market 25% of the gasoline pool - (4 billion gal/yr)
  - Value: 82 ¢ to 99¢ per gallon
  - Potential of 125 gal/ton of lignin
    - 10 to 35 gal/ton of biomass feedstock
    - $ 7 MM to $25 MM/yr revenue (2000 T/d biomass)

Higher Value Products from Lignin Stream

	Market MM lb/yr	Price $/lb	Fraction of Market*	Revenue** MM $/yr
Surfactants for Oil Rec.	15,000	$0.67	3%	$ 8
Charcoal	1,600	$0.16	26%	$ 18
Lignin Surfactants	1,000	$0.12	42%	$ 21
Activated Carbon	240	$1.04	173%	$ 433
Antraquinone	133	$4.00	313%	$ 1,663
Hydroquinone	37	$2.16	1124%	$ 899
Lignin Available Min	125			
Lignin Available Max	416			

* Based on one 2000 T biomass/day plant
** Based on one 2000 T biomass/day plant or 100% of Market

Sugar Platform Summary

- Focusing on a “Sugar Platform” will:
  - Allow independent optimization of hydrolysis and fermentation
  - Attract near term industrial partners
  - Facilitate near-term commercialization of sugar products
    - Ethanol production from sugar is a known art